PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) FLOW INDICATING DEVICE

(71) We, ESSO RESEARCH AND ENGINEERING COMPANY, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Linden, New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the indication and measurement of fluid flow.

It is often desirable to know whether or not there is any flow in a liquid or gas carrying conduit and the rate at which the flow is taking place. Many of the devices used for indicating fluid flow create substantial disturbances which impede the fluid flow or cannot be employed where the range of flow rates to be indicated or measured is very large. Furthermore there are many prior fluid flow indicating devices which give no indication of the direction of fluid flow.

The present invention provides the combination of a conduit or flow channel in which a stream of fluid can flow and a flow indicating device comprising a resilient probe, means for rigidly holding one end of the probe so that it will project into the path of the stream of fluid and means for indicating any deflection of the probe due to fluid flow in the conduit or channel, there being means provided by or associated with the conduit or channel for disengageably engaging against the probe for forming a seal to prevent leakage between the interior and the exterior of the conduit or channel.

The probe is preferably supported from the walls of the fluid-carrying conduit or flow channel, during use, and a deflection of the probe from its normal configuration will give an indication of fluid flow in the conduit or channel. The degree of deflection of the probe will be related to the fluid flow rate and by calibration of the probe deflection at known fluid flow rates, the device may be employed to give absolute measurements of fluid flow rate.

The deflection indicating means may comprise a strain gauge mounted on the probe, and the strain gauge may be of the resistance type formed from either metal foil or resistance wire. Any deflection of the probe will bring about a corresponding change in the resistance of the strain gauge. The type of change in the resistance (i.e. an increase or a decrease) of the strain gauge depends on the direction of deflection of the probe and hence on the direction of motion of the fluid. Accordingly the device of the invention provides, in addition to an indication of the flow of fluid, an indication of the direction of fluid flow.

The deflection indicating means may further comprise means for measuring changes in the resistance of the resistance strain gauge.

In order to provide a flow indicating device of increased sensitivity, the deflection indicating means may comprise two strain gauges mounted on opposite sides of the probe. For convenience, where the strain gauges are of the resistance type, they may form two arms of a Wheatstone's bridge network so that any deflections of the probe are determinable by changes in the balance of the bridge network.

In another form of the invention, the indicating means may comprise a piezo-electric element, and there may be means for detecting changes in the e.m.f. across the piezeo-electric element to provide an indication of deflections of the probe due to the flow of the fluid. There may be two piezo-electric elements mounted on opposite sides of the probe.

The deflectable probe of the device may have any cross-section which is suited to the expected flow characteristics of the fluid. For generally non-turbulent flow, the probe may take the form of a flat-sided vane or reed best employed with the flat sides facing respectively upstream and downstream, while for use generally in turbulent flow regimes, the probe may be of circular or eliptical cross-section. Where the device is intended for flow indication in very high speed fluid flows, a probe of aerofoil cross-section may be em-

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ployed; in this latter case, the chord of the aerofoil would be preferably disposed substantially parallel to the direction of flow and the resulting deflections would take place generally at right angles to the chord.

The probe may be integral with, and project inwardly in the plane of, an annular member of such dimensions that the annular member may be trapped between two abutting flanges of successive pipes or conduit-lengths ,with the probe projecting into the flow-path of the fluid.

Alternatively, the probe of the device may be adapted to be received in the flow-path of the fluid through an aperture in the channel or conduit, and there may be suitable valves and /or seals for engagement with the probe or other parts of the device to prevent egress of the fluid through the aperture.

The invention includes an installation comprising a flow indicating device as hereinbefore described in combination with a fluid conduit or flow channel, and the invention comprises, in another aspect, a method of indicating or measuring fluid flow employing a flow indicating device as described in the foregoing paragraphs. The fluid may be a liquid or a gas, or any material which is capable of behaving like a fluid.

A number of non-limitative embodiments of the invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 is a cross-sectional view through a pipe showing one form of device in an operational position,

Figure 2 is an elevational view of the device of Figure 1,

Figure 3 shows a part of the device of Figures 1 and 2 in greater detail in transverse cross-section,

Figure 4 shows the part depicted in Figure 3 in elevation with a portion removed to illustrate some constructional features,

Figure 5 shows in cross-section another form of a device in accordance with the invention,

Figure 6 is a cross-sectional view of another device, and

Figure 7 shows, on a larger scale, a part of the view of Figure 6, but incorporating a modification.

Referring first to figures 1 and 2, the probe 10 has the form of a deflectable reed or vane which is integral with, and cantilevers inwardly from, an annulus 11 of suitable material. The probe 10 has been positioned in a fluid carrying conduit 12 by trapping the annulus 11 between the two abutting flanges 13 of successive lengths of pipe 14. The flat sides of the probe 10 are presented respectively in the upstream and downstream directions.

The fluid flow is from left to right as indicated by the arrows 15 in figure 1, and it will be seen that the free end of the probe 10 is deflected from the plane of the annulus 11 in the direction of flow. The degree of deflection of the probe 10 is dependent on the fluid flow rate.

Referring now to figures 3 and 4, it will be seen that the probe 10 comprises a flexible shim 16 of, for example, phosphor-bronze, and two resistance strain gauges 17, 18 of the foil type attached by soldering or spot-welding to the upstream and downstream faces of the probe 10. The gauges 17, 18 are positioned somewhat distally from the free end of the probe 10 as a position which is subject to a suitably large bending moment when the probe 10 is deflected, and the gauges are connected to a resistance measuring circuit such as a Wheatstone's bridge network (shown later in figure 5) by means of suitable insulated leads 19, 20. Generally speaking, the most suitable position for the strain gauges will be about one third of the distance along the probe from its restrained end. The shim 16 serves as the return lead and is connected to the network via lead 21.

The shim 16 and gauges 17, 18 are embedded in an inert electrically non-conductive sheath 22 of a suitable resin or ceramic material which will permit the deflection of the probe 10.

While one of the gauges 16, 17 is in tension due to deflection of the probe 10 in one direction, the other gauge 17, 16 will be in compression. Hence both gauges 16, 17 will detect changes due to deflection of the probe 10, and the detection of fluid flow will be roughly twice as sensitive as would be the case where only one strain gauge were provided in the probe 10. Although this latter arrangement forms a useful embodiment of the invention, it is subject to the disadvantage that the characteristics of the single gauge would change with changes in temperature, and without a temperature correction, its resistance would not give accurate indications of fluid flow. Accordingly, a probe having a single strain gauge would find most application in systems of relatively constant temperature, although the errors arising from the absence of a temperature correction might not be very serious over small temperature ranges. It also is possible to calibrate a probe having a single gauge to take account of temperature variations for each fluid whose flow is to be investigated

In the embodiment of figures 3 and 4, while the probe 10 is integral with an annulus 11, it will be appreciated from the drawings that the annulus 11 is multilayered and may incorporate suitably compressible gasket material such as asbestos between metal facing annuli. The shim 16, leads 18, 20 and the radially outer region of the sheath 22 are embedded in, and thus form part of, the annulus 11.

The probe 10 of figure 5 comprises a thin stainless steel sheath 25 filled with resin or ceramic material 26 in which are embedded a central copper wire 27 between two resistance elements 28, 29. The resistance wires 28, 29 join the central wire 27 near the free end of the probe 10 and are connected into a Wheatstone's bridge network 30, as shown in figure 5, at their radially outer ends by means of leads 31, 32 respectively. The central wire 27 serves as a return lead and is connected to the galvanometer 33 of the network 30. The network 30 is supplied with a.c. or d.c. electric power by a source A and has a fixed resistance 34 and a variable resistance 35.

The flow-indicating device is calibrated by passing known flow-rates through the conduit 12 and adjusting the resistance 35 until no deflection is registered by the galvanometer 33.

In the embodiment of figure 5, the probe 10 is received through an aperture 37 in the wall of the pipe 14. This is convenient since it enables the probe 10 to be inserted and removed from the conduit 12 without the need to separate successive pipe-lengths as would be the case with the previous embodiments.

To prevent fluid leakage through the aperture 37, the probe 10 is received through a valve 38 and a sealing gland 39.

In a practical embodiment, a probe 10 having the form depicted in figures 1 to 4 was made and arranged to be inserted in a pipeline in the manner shown in figure 5. The widest part of the probe 10 was half an inch wide and one inch long, and the strain gauges 17, 18 were mounted on a narrow neck, $\frac{1}{4}$ inch wide and $\frac{1}{2}$ inch long. The probe 10 was made from a flexible steel hacksaw blade and was coated with a silicone rubber to avoid corrosion and to dampen any tendency of the probe 10 to oscillate. It was possible to measure vapour flows of from 1 ft./sec to 40 ft./sec satisfactorily with a device of this type.

The device 10 shown in figure 6 is suitable for insertion into the fluid flow channel through an aperture in the wall of a pipe, a valve sealing gland being desirable to prevent leakage of the fluid. The arrangement of the aperture, valve and gland may be substantially of the form depicted in figure 5.

The device 10 of figure 6 comprises a resilient flat-sided probe 51 of brass or spring steel which is cantilevered out from its right hand end (as shown), the right hand end being fixedly located in a generally tubular holder 52, of stainless steel. The holder 52 is crimped at its left hand end (as shown) onto the right hand end of the probe 51. On the flat sides of the probe 51 are mounted suitable deflection-indicating means—in this case piezo-electric elements or wafers 53, 54, and the e.m.f. across each element 53, 54 is transmitted to a suitable e.m.f. measuring device such as an electrometer by means of respective insulated conducting wires 55, 56, there being provided a common "earth" conducting wire 57 from the probe 51 which is available for connection to the e.m.f. measuring device (not shown) when measurements are to be made. The piezo-electric elements or wafers 53, 54 may be of any material which generates an e.m.f. on distortion provided that the material will withstand the intended conditions of operation to which they will be subjected.

For simplicity of construction, and where the type of fluid whose flow is to be investigated permits, the conducting wires 55, 56 extend along the exposed part of the probe 51 between the piezo-electric elements 53, 54, and then into the holder 52 through apertures in the vicinity of the crimped region thereof. The "earth" conducting wire 57 is connected to that end of the probe 51 within the holder 52. All three conducting wires 55, 56 and 57 extend out of the other end of the holder 52, the said other end being closed, as shown.

The interior of the holder 52 is filled with a solid resin which will remain solid and chemically stable at the temperatures likely to be encountered: for most applications, an epoxy-type resin is suitable. The solid resin filling improves the robustness of the device 10.

In a particular embodiment of the device 10, the probe 51 was about $\frac{1}{8}$ inch wide and about $1\frac{1}{2}$ inches projected from the holder 51. The piezo-electric elements were disposed about $\frac{1}{2}$ from the crimped end of the holder 52. The holder was a tube of about $\frac{3}{8}$ inch internal diameter. To improve the durability of the device 10, the modification shown in figure 7 may be adopted, in which a rivet 60 passes through the crimped part of the holder 52 and the crimped end of the probe 51.

It will be appreciated that as well as providing an indication of fluid flow, the magnitude of fluid flow and direction of flow, the device of the invention may form part of a control system in which the measured deflections of the probe due to the fluid flow are arranged to provide signals which regulate the flow of fluid.

By means of the invention, fluid flow rates may be determined without greatly disturbing the fluid flow, and with relatively great sensitivity even at low flow rates. Furthermore, the device according to the invention provides information on the direction of fluid flow.

WHAT WE CLAIM IS:—

1. The combination of a conduit or flow channel in which a stream of fluid can flow and a flow indicating device comprising a

resilient probe, means for rigidly holding one end of the probe so that it will project into the path of the stream of fluid and means for indicating any deflection of the probe due to fluid flow in the conduit or channel, there being means provided by or associated with the conduit or channel for disengageably engaging against the probe for forming a seal to prevent leakage between the interior and the exterior of the conduit or channel.

2. The combination according to claim 1 in which the deflection indicating means comprises a strain gauge.

3. The combination according to claim 2 in which the strain gauge is of the resistance type and is formed from either metal foil or resistance wire.

4. The combination according to claim 3 comprising means for measuring changes in the resistance of the strain gauge.

5. The combination according to claim 2 in which the strain gauge comprises a piezo-electric element.

6. The combination according to claim 5 comprising means for detecting changes in the e.m.f. across the piezo-electric element.

7. The combination according to any of claims 2 to 6 in which the probe has a strain gauge mounted on each of two opposite sides of the probe.

8. The combination according to any preceding claim in which the probe is integral with, and projects inwardly in the plane of a flat-sided member which constitutes the means for rigidly holding said one end of the probe and which member can be trapped between the ends of successive lengths of the conduit or channel in which the fluid is to flow, said ends constituting the disengageable engaging means.

9. The combination according to any of claims 1 to 7 in which the wall of the conduit in which the fluid is to flow is provided with an aperture through which the probe may project and the means for disengageably engaging against the probe for forming a seal comprises a sealing gland.

10. The combination according to claim 9 in which there is provided a valve for closing said aperture when the probe is not in the aperture and through which, when the valve is open the probe may be passed into said aperture.

11. The combination according to any of claims 1 to 7 or claim 9 or claim 10 in which the means for rigidly holding the said one end of the probe comprises a hollow member which is crimped onto the said one end of the probe.

12. The combination according to any preceding claim in which the probe is in the form of a flat-sided vane or reed, or has a circular or elliptical cross-section.

13. The combination according to any of claims 1 to 11 in which the probe is of aerofoil form.

14. The combination in accordance with any one of claims 1 to 13 in which the conduit or channel and the resilient probe are assembled so that the probe projects into the path which is taken by the stream of fluid during operation.

15. The combination substantially as hereinbefore described with reference to figures 1 to 4, or to figure 5 or to figure 6 or to figure 7 of the accompanying drawings.

16. A method of investigating the flow of a fluid which comprises connecting the assembled combination of claim 14 or claim 15 to a source of the fluid and deriving a signal indicative of any fluid flow from the means for indicating deflections of the probe.

17. A method according to claim 16 is which the flow of fluid is regulated by signals derived from the deflection-indicating means.

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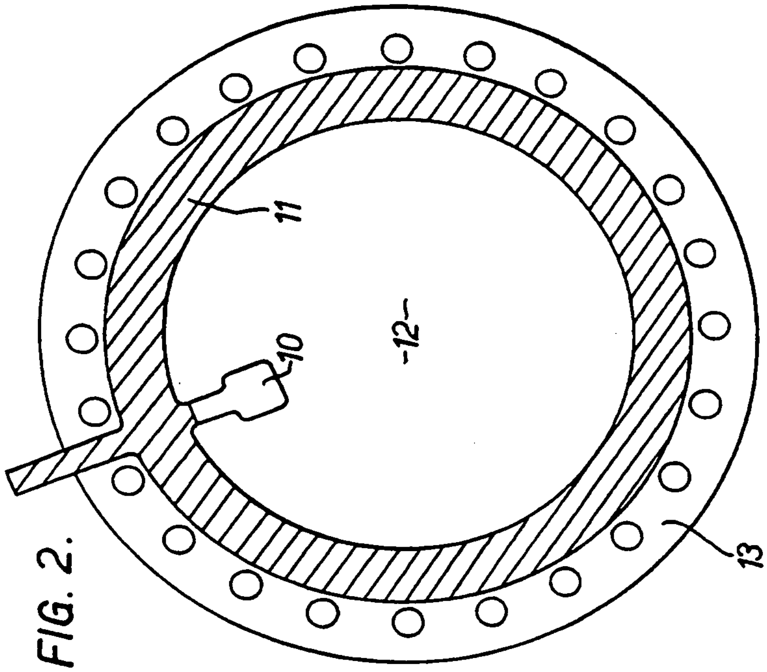


FIG. 2.

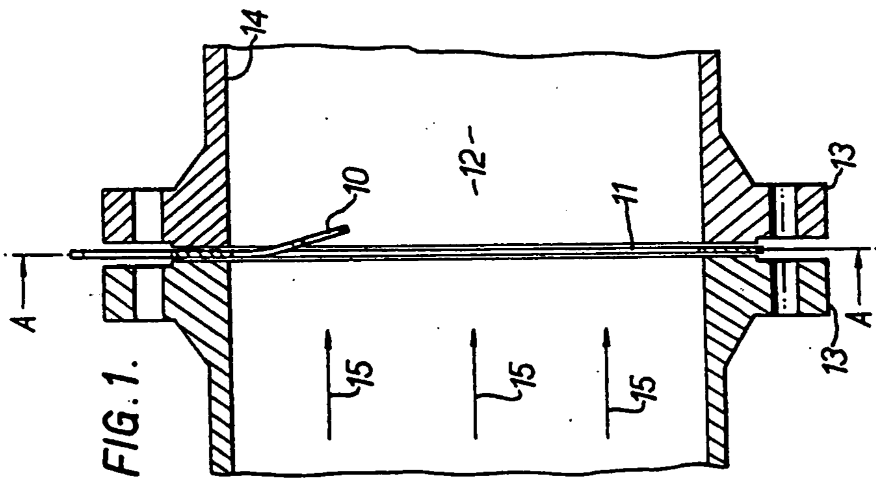


FIG. 1.

FIG. 3.

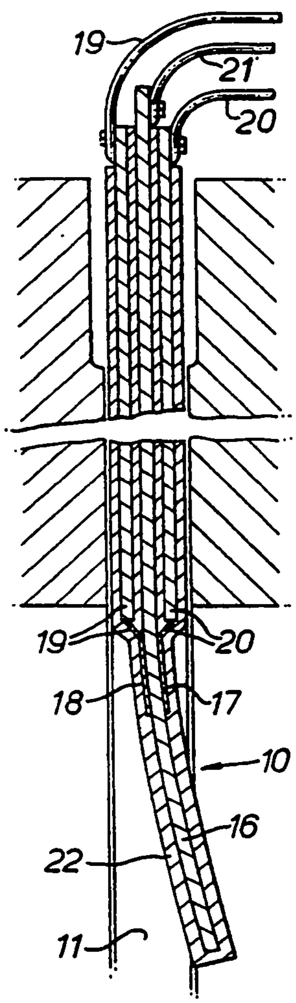
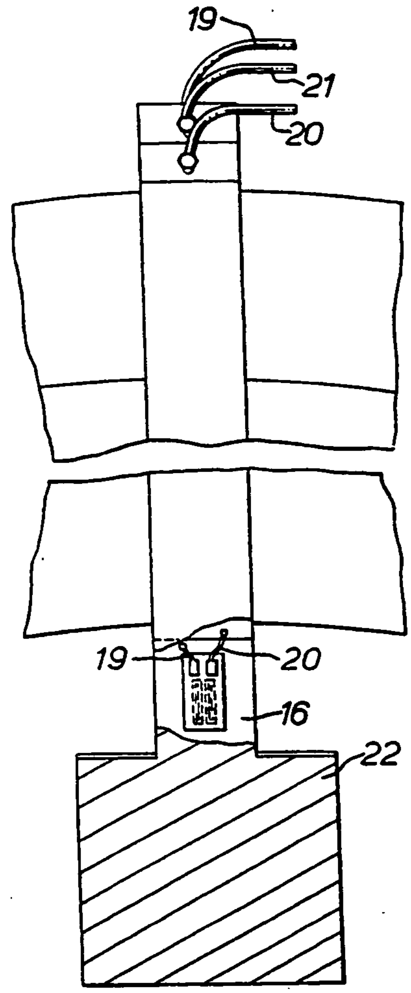


FIG. 4.



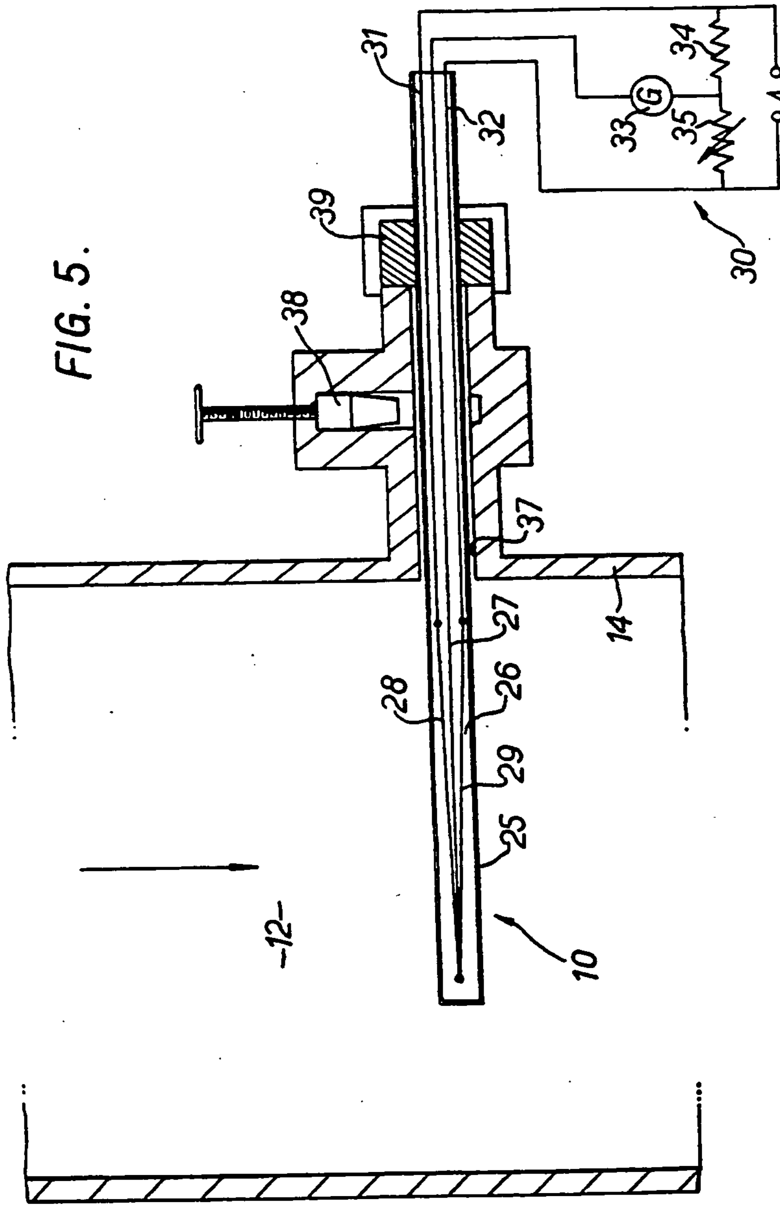


FIG. 5.

1252433 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

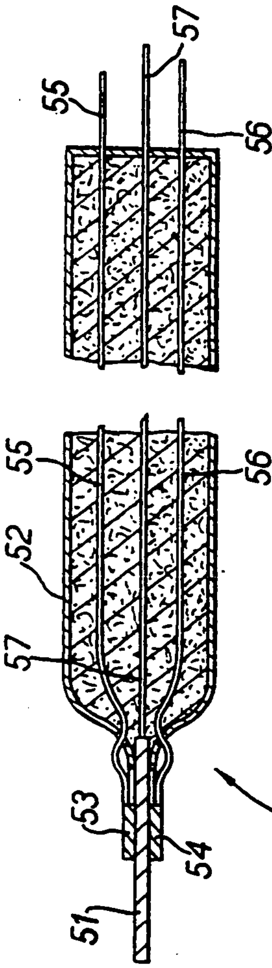


FIG. 6.

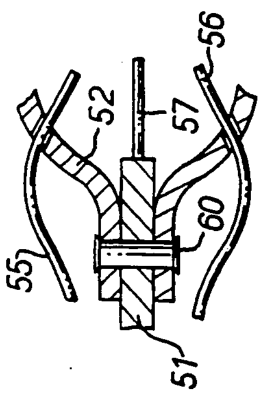


FIG. 7.